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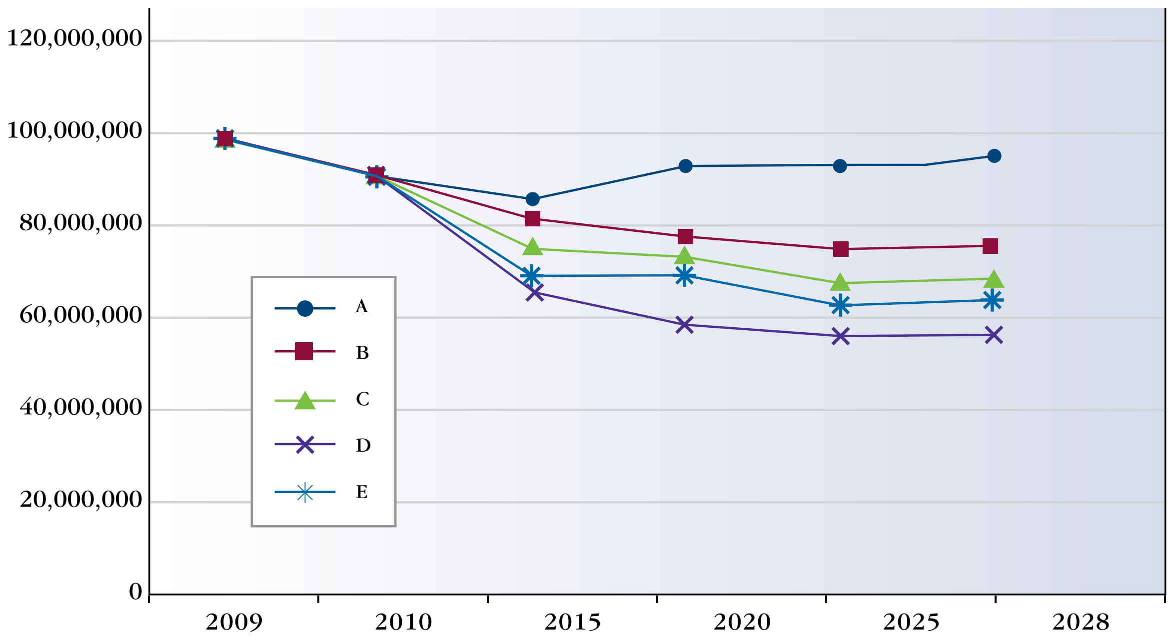
Appendix A – Method for Computed Environmental Impact Metrics

Air Impact Metric and Ranking

Model results provided data on the production of four emissions: carbon dioxide (CO_2), sulfur dioxides (SO_2), nitrogen oxides (NO_X) and mercury (Hg) by generation source (e.g. coal, lignite, etc.). It was suspected that evaluating the strategies on the basis of all four emissions would give the same results as just using CO_2 alone, but emission trend plots were developed to confirm this assumption. Emission trends were plotted against averaged, historic TVA generation data from 2007–2009 for coal and combustion turbines (CTs). The most recent three years were used to provide a better representation of average air emissions, as 2009 was a historically low year for air emissions due partly to the economic recession and decreased electricity demands. Historic mercury emissions for lignite sources were unavailable, so projected data for 2010 was used and added to the other totals.

Again using model results by generation sources for each of the cases, CO_2 emissions data from all emission sources were summed for selected spot years (five-year increments) 2010, 2015, 2020, 2025 and 2028. Then for each of these years, the CO_2 emissions for each strategy (A–E) were summed across all seven worlds – this gives a value for the total CO_2 emissions associated with each strategy. These totals were divided by seven to provide a representative average value for each spot year that could be compared to the 2007–2009 averaged historical data. These data were plotted to demonstrate how CO_2 emissions vary over time (see Figure A-1).

Figure A-1 – Tons CO_2 by Strategy



Similar calculations were also done for SO_2, NO_X, and Hg – figures are shown below.

Figure A-2 – Tons SO_2 by Strategy

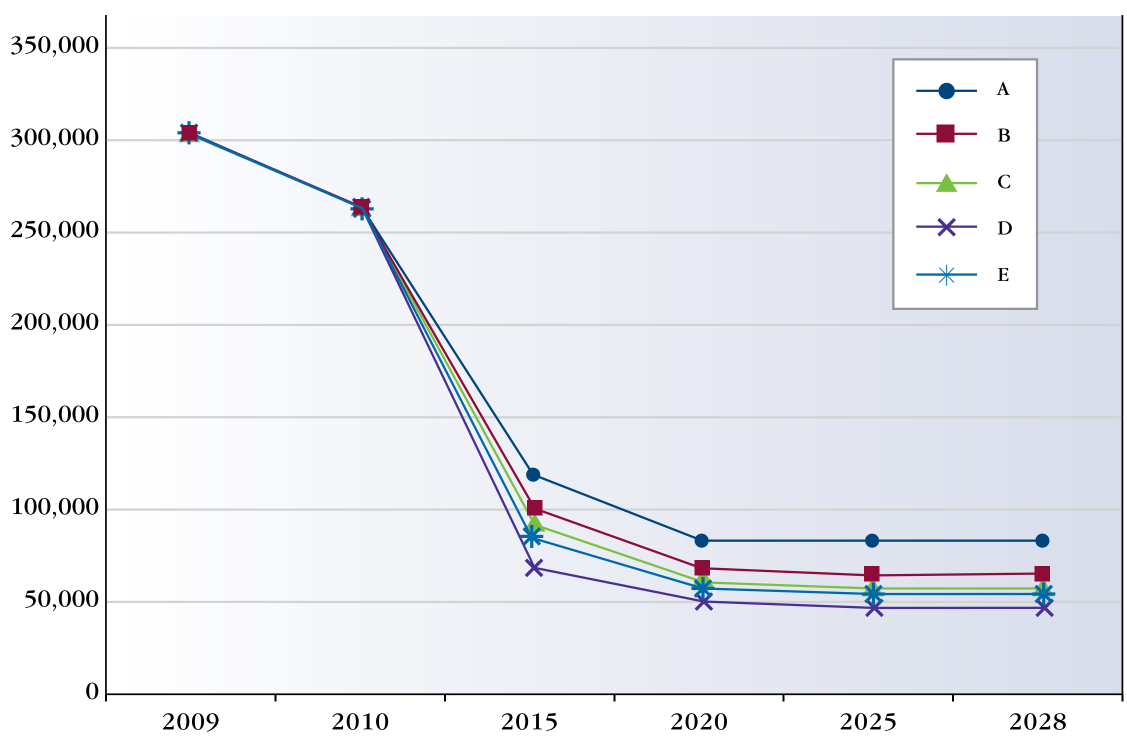


Figure A-3 – Tons NO_X by Strategy

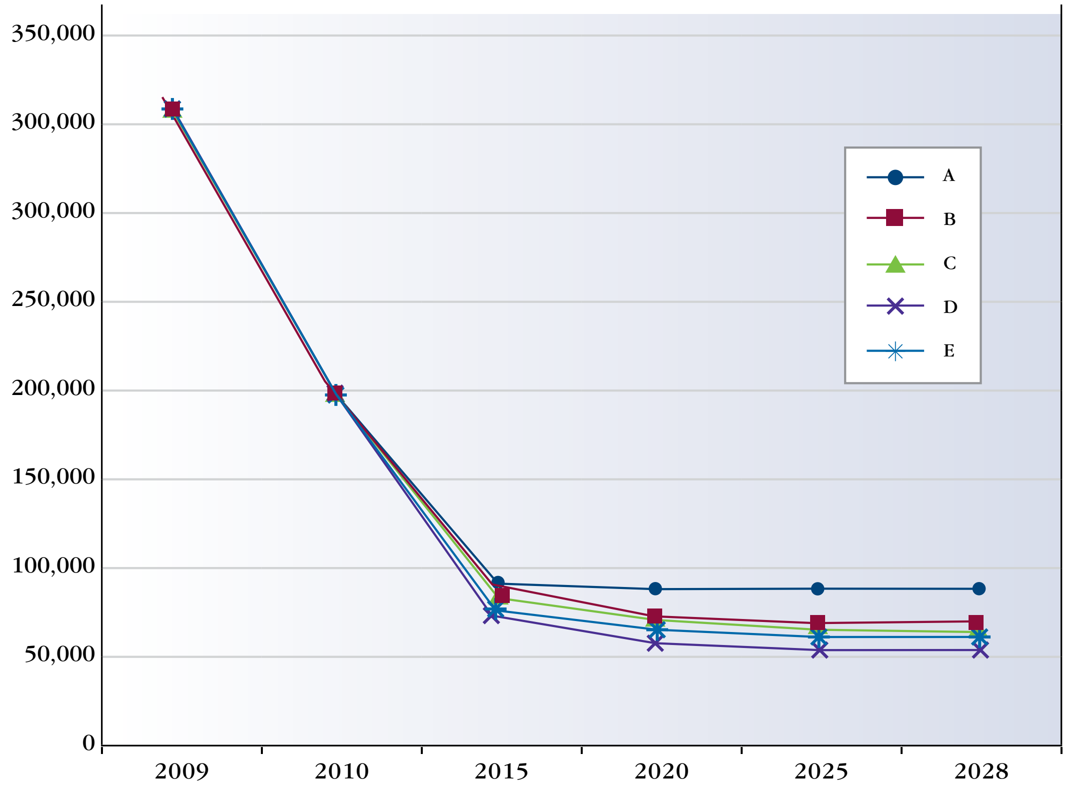
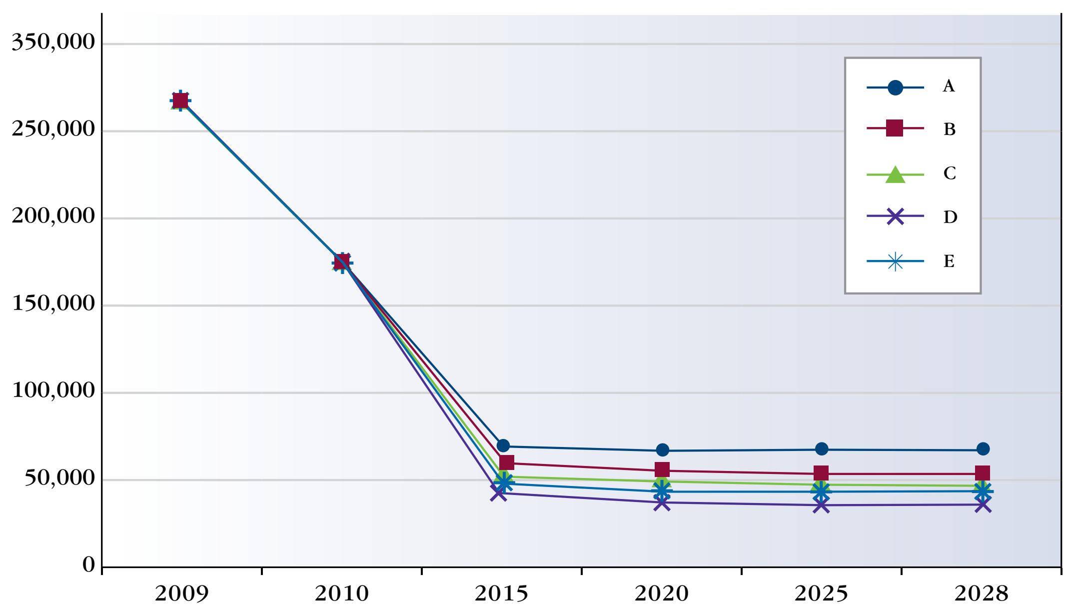


Figure A-4 – Lbs HG by Strategy



These plots show that, in general, all emissions decrease over time with the exception of CO_2 in Strategy A, which does not include any fossil layups. They also show that all five strategies result in similar performance in terms of reductions in emissions over the spot years, thus confirming that CO_2 is an appropriate proxy for the trend in all air emissions.

To further verify that all five strategies' performance on all four emissions give the same rankings, the total yearly emissions from all sources for each strategy across all seven worlds were summed for five spot years and used to rank the strategies for each emission. Figure A-5 shows the results of these rankings, again confirming that the CO_2 ranking alone gives the same information as using information on all four emissions.

Figure A-5 – Strategy Rankings for All Four Emissions

Strategy	SO_2	NO_X	Hg	CO_2
A	5	5	5	5
B	4	4	4	4
C	3	3	3	3
D	1	1	1	1
E	2	2	2	2

It should be noted that using CO_2 alone appears to penalize Strategy A since CO_2 emissions do not decline over the time period as the other emissions decline. This is due to the assumptions under Strategy A that no fossil plants are laid up but SO_2 and NO_x emission controls are installed.

Water Impact Metric and Ranking

The major way thermal generating plants impact water is by the amount of heat they reject to the environment. IRP strategies were evaluated on the basis of the BTUs delivered to the plants' condensers, which is where rejected heat is transferred. The calculation involves taking the generation sources shown in Figure A-6 and multiplying their generation (GWh) by heat rate (BTU/kWh) (with unit conversions) by a design factor for the specific generation technology.

Figure A-6 – Design Factors for Generation Sources

Generation Source	Design Factor
Coal	51%
Combined Cycle (CC)	11%
Future Integrated Gasification CC	27%
Future Super Critical Pulverized Coal (SCPC)	46%
Lignite	51%
Uranium	66%

The heat rejected to the environment (BTUs) is summed for all five spot years (2010, 2015, 2020, 2025, 2028) and all generation sources for each case. For each world (1–7), the strategies (A–E) are compared to each other and ranked. A preferred strategy is the most robust (i.e., performs the best across all seven worlds). Therefore, we sum the rankings of each strategy in each world, and re-rank them on the basis of their total score. A strategy that performed the best in each of the seven worlds would have a total score of 7 (1 x 7), and a strategy that performed the worst in all seven worlds would have a score of 35 (5 x 7). The total scores and associated final ranking is shown in Figure A-7 below.

Figure A-7 – Final Strategy Water Impact Ranking

Worlds	Strategy				
	A	B	C	D	E
1	3	5	4	2	1
2	4	5	3	2	1
3	5	4	3	1	2
4	4	5	3	2	1
5	4	5	3	1	2
6	5	4	3	1	2
7	4	5	3	1	2
Sum of Rankings	29	33	22	10	11
Final Ranking	4	5	3	1	2

Waste Calculations

The metric used to rank strategies in terms of their waste impact (coal and nuclear) is the cost of handling the waste generated—the assumption is that the costs of disposal, in accordance with all applicable regulations, is a proxy for the wastes' impacts on the environment. Handling costs are based on actual, historical TVA averages, expected future handling costs based on operations and transportation estimates.

Coal waste comes from two sources: coal burning and scrubber sludge. Coal waste for TVA plants was calculated using weighted coal ash and heated content (BTU/lb) values from 2009 historical data. The weighted averages are shown in Figures A-8 and A-9.

Figure A-8 – Weighted Ash Percentage

Year	Strategy				
	A	B	C	D	E
2010	8.19%	8.19%	8.19%	8.19%	8.19%
2015	8.19%	8.04%	7.91%	8.71%	8.15%
2020	8.19%	8.04%	7.91%	8.99%	8.15%
2025	8.19%	8.04%	7.91%	8.99%	8.15%
2028	8.19%	8.04%	7.91%	8.99%	8.15%

Figure A-9 – Weighted Heat Content (BTU/lb)

Year	Strategy				
	A	B	C	D	E
2010	11,033	11,033	11,033	11,033	11,033
2015	11,033	11,004	10,948	11,556	11,134
2020	11,033	11,004	10,948	11,809	11,134
2025	11,033	11,004	10,948	11,809	11,134
2028	11,033	11,004	10,948	11,809	11,134

For each strategy (A–E), from the model results, the fuel consumed (mmBTU) for TVA coal was multiplied by 1 million to get the units into BTUs, then multiplied by the coal fuel conversion values (from the weighted BTU/lb figure), and then multiplied by the percentage ash value (from the weighted ash figure). The product was then divided by 2000 to get an answer in tons. A handling cost ($/ton) is then applied to the calculation.

Coal waste from the lignite plant under contract to TVA was calculated based on fuel consumed (mmBTU), divided by 5,234 BTU/lb, multiplied by 14.64% ash content (based on Mississippi lignite source information), and divided by 2000 to get an answer in tons. A handling cost ($/ton) is then applied to the calculation.

Coal waste from future Integrated Gasification Combined Cycle (IGCC) was calculated by multiplying generation times 62lb/MWh (slag production) and divided by 2000 to get an answer in tons. Coal waste from future Super Critical Pulverized Coal (SCPC) was calculated by taking the fuel consumed (mmBTU), divided by 8,803 BTU/lb, multiplied by 4.83% ash content (average Powder River Basin coal values), and divided by 2000 to get an answer in tons. A handling cost ($/ton) is then applied to the calculation.

For 2010 scrubber waste, waste is calculated by taking fuel consumed (mmBTU), multiplied by 0.5 (about 50% of TVA generation is now scrubbed), times 11 lbs/mmBTU (average of TVA existing fleet). For future year calculations, it was assumed that all remaining TVA coal generation (based on fossil layup assumptions) are scrubbed. Waste is calculated by multiplying fuel consumed by 11 lbs/mmBTU. A handling cost ($/ton) is then applied to the calculation.

The combined coal and nuclear waste handling costs are used to rank all five scenarios. All fossil waste costs (including lignite and future base generation) and nuclear waste costs are summed for all five spot years (2010, 2015, 2020, 2025, 2028) and all generation sources for each case. For each world (1–7), the strategies (A–E) are compared to each other and ranked with the strategy having the lowest waste handling cost (ranked #1) and the strategy with the highest costs (ranked #7).

A preferred strategy is the most robust (i.e., it performs the best across all seven worlds). Therefore, we sum the rankings of each strategy in each world, and re-rank them on the basis of their total score. A strategy that performed the best in each of the seven worlds would have a total score of 7 (1 x 7) and a strategy that performed the worst in all seven worlds would have a score of 35 (5 x 7). The total scores and associated final ranking is shown in Figure A-10 below.

Figure A-10 – Final Strategy Waste Impact Ranking (Based on Total Coal and Nuclear Waste Disposal Costs)

Worlds	Strategy				
	A	B	C	D	E
1	3	5	4	1	2
2	4	5	3	1	2
3	5	4	3	1	2
4	3	5	4	1	2
5	4	5	3	1	2
6	4	5	3	1	2
7	3	5	4	1	2
Total	26	34	24	7	14
Ranking	4	5	3	1	2

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Appendix B – Method for Computed Economic Impact Metrics

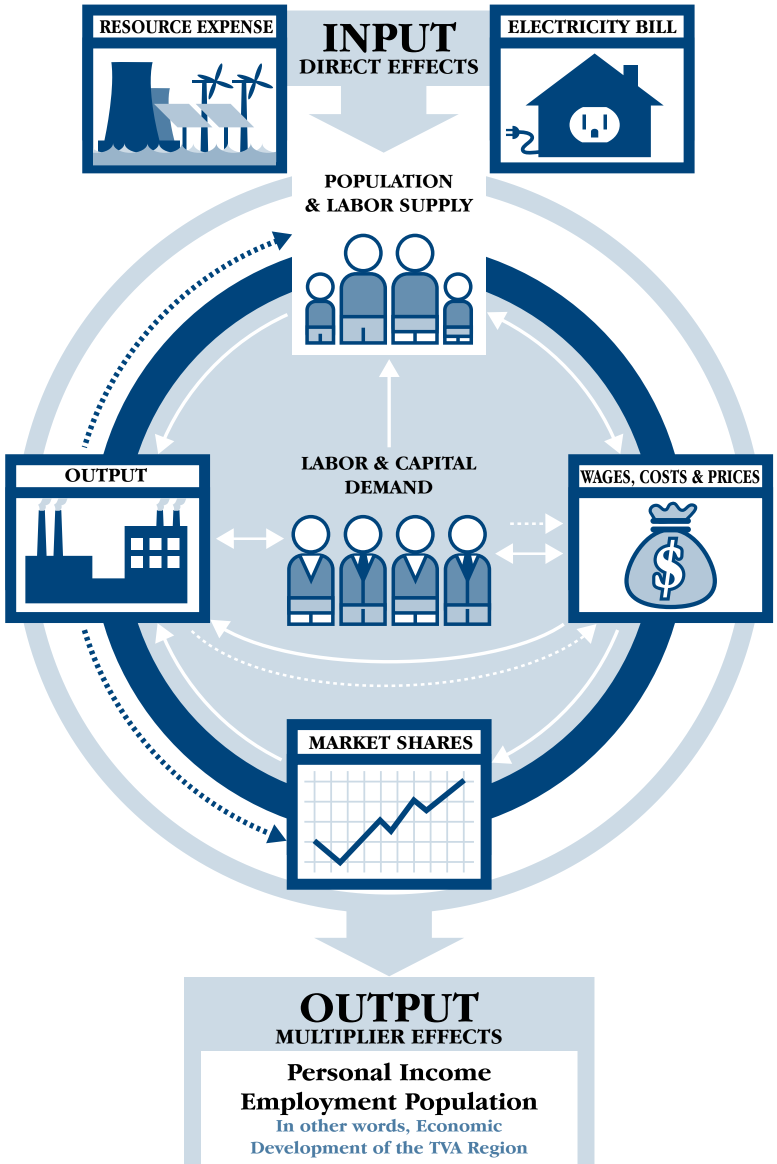
Regional Socioeconomic Impacts

Economic metrics are included to provide a general indication of the impact of each strategy on the general economic conditions in the TVA service area, represented by the change in total employment and personal income indicators as compared to the impacts that would be realized under Strategy B (Baseline Plan Resource Portfolio) in Scenario 7. The process used is, on the whole, the same as has been used at TVA for programmatic region-wide EIS dating back to the 1979-80 PURPA study. It is also, in general, the same as that used by other models/studies. This process is described below.

Process

As shown in Figure B-1, on the following page, direct expenses by TVA in the region on labor, equipment and materials stimulate economic activity. At the same time, the costs of electricity to customers (the bills customers pay, including savings from energy efficiency) take away from the income that customers could use to buy goods and services in the region.

Figure B-1 – Input/Output Effects



These "direct effects" are input into a regional economic model, which captures the interactions within the regional economy – the so-called multiplier effect. TVA uses a Regional Economic Models, Inc. (REMI) model of the economies of the TVA region and surrounding areas. This model maps the Valley's economic structure, its inter-industry linkages, and responses to TVA rate and customer cost changes, including from energy efficiency. Along with the TVA region economy relations, the model also captures interactions with areas outside the Valley, such as for coal purchases from outside the Valley.

The analysis includes data on direct TVA expenditures in terms of applicable payrolls, material and supply purchases, and fuel costs for all energy resource options that comprise a particular strategy for both construction and operations. It also includes data on TVA rates/total resource cost resulting from each strategy and savings to customer bills from energy efficiency/demand reduction programs.

Methodology

Annual construction expenses were entered into the regional economic model for each strategy/scenario analyzed. The model then calculated two types of indirect effects from construction expenses:

- The increase in goods manufactured in the Valley, as a result of purchasing materials and supplies in the region associated with a project.
- The additional income generated in the regional economy, resulting from spending by workers hired for the purpose of the construction activity.

The analysis of operations was similar to that for construction. Annual operations expense data for the strategy portfolio was entered into the economic model. Given fuel purchase patterns, most of these purchases came from outside the region and were entered into the analysis as expenses in areas outside the region.

The analysis also estimated the effects of cost differences among strategies. Differences in customer cost, or electric bills, add to or subtract from the spending capacity of customers and thus affect the amount of income/revenue available for other uses. Such income, when returned to the economy, generates additional economic growth. Estimates of annual total resource costs for each strategy, as well as net savings from energy efficiency/demand reduction programs to customers, were used to estimate net cost differences among strategies. These were used with the TVA regional economic model to compute the impacts.

All of the IRP strategies were analyzed for Scenario 1 and Scenario 6, the scenarios that were determined to define the upper and lower range of the impacts of the strategies within the scenario range. The factors discussed above were incorporated into the regional economic model for each strategy/scenario in order to measure the overall economic development effects for each strategy/scenario, including indirect effects. Overall, economic impacts are the net effect of both direct factors—resource expenses and customer electricity bills—as measured in terms of employment and income changes from the base case, Strategy B (Baseline Plan Resource Portfolio) in Scenario 7, due to both the direct and indirect economic impacts.

Findings

In terms of percent difference in the overall Valley economy as measured by both employment and income, the major finding is that there was no significant change (differences were around 1% or less) in both the short- and long-term for the range of strategies and scenarios. Although none of the strategies portrayed significant differences from the base case, there were differences in a relative sense as shown in Figure B-2 below.

As shown in the figure, Strategy A performed worse than any of the other strategies for the scenario range. Strategies B, C, D and E had more comparable results, within a few tenths of a percent difference. The impacts of Strategy B and Strategy D were very similar, performing better in the high growth Scenario 1 than C or E, but worse in the low growth Scenario 6 than C or E or the base case. This is consistent with strategies that lean towards building to meet load, versus C and E which lean towards conservation. Strategy C and Strategy E's impacts were very similar, performing above the base case in the long-term under both Scenario 1 and Scenario 6.

Figure B-2 – Final Summary Economic Impacts of IRP Cases

		Percent difference from IRP Base Case			
		Total Employment		Total Personal Income	
Stategy	Scenario	Average 2011-2028	Average 2011-2015	Average 2011-2028	Average 2011-2015
A	1	0.1%	-0.4%	0.1%	-0.2%
	6	-0.4%	-0.4%	-0.4%	-0.3%
B	1	1.0%	0.3%	0.8%	0.3%
	6	-0.3%	-0.4%	-0.3%	-0.3%
C	1	0.9%	0.2%	0.6%	0.2%
	6	0.2%	-0.2%	0.1%	-0.1%
D	1	1.2%	0.4%	1.0%	0.3%
	6	-0.1%	-0.4%	-0.2%	-0.4%
E	1	0.8%	0.0%	0.6%	0.0%
	6	0.3%	-0.1%	0.2%	-0.1%

Scenario

1 Economy Recover Dramatically
2 Environmental Focus is a National Priority
3 Prolonged Economic Malaise
4 Game-Changing Technology
5 Energy Independence
6 Carbon Legislation Creates Economic Downturn
7 Current Situation

Planning Strategy

A Limited Change in Current Resource Portfolio
B Baseline Plan Resource Portfolio
C Diversity Focused Resource Portfolio
D Nuclear Focused Resource Portfolio
E EEDR and Renewables Focused Resource Portfolio

Baseline is Scenario 7, Strategy B

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Appendix C – Expansion Plan Listing

Figure C-1 – Planning Strategy A – Limited Change in Current Portfolio

Year	Defined Model Inputs			Capacity Additions by Scenario						
	EEDR	Renewables	Fossil Layups	SC1	SC2	SC3	SC4	SC5	SC6	SC7
2010	246	35	-							
2011	408	48	-							
2012	421	137	-	JSF CC	JSF CC	JSF CC	JSF CC	JSF CC	JSF CC	JSF CC
2013	666	155	-	WBN2	WBN2	WBN2	WBN2	WBN2	WBN2	WBN2
2014	1733	155	-							
2015	1434	160	-	GL CT Ref	GL CT Ref		GL CT Ref	GL CT Ref		GL CT Ref
2016	1557	160	-							
2017	1684	160	-							
2018	1812	160	-							
2019	1940	160	-							
2020	2051	160	-							
2021	2069	160	-							
2022	2014	160	-							
2023	2061	160	-							
2024	2131	160	-							
2025	2085	160	-							
2026	2226	160	-							
2027	2076	160	-							
2028	1980	160	-							
2029	1905	160	-							

Figure C-2 – Planning Strategy B – Baseline Plan Resource Portfolio

Year	Defined Model Inputs			Capacity Additions by Scenario						
	EEDR	Renewables	Fossil Layups	SC1	SC2	SC3	SC4	SC5	SC6	SC7
2010	229	35	-	PPA's & Acq			PPA's & Acq			
2011	385	48	(226)							
2012	384	137	(226)	JSF CC	JSF CC	JSF CC	JSF CC	JSF CC	JSF CC	JSF CC
2013	610	155	(935)	WBN2	WBN2	WBN2	WBN2	WBN2	WBN2	WBN2
2014	1363	155	(935)	CTa CT GL CT Ref			CTa		GL CT Ref	
2015	1496	160	(2,415)	CT CC	GL CT Ref		GL CT Ref CT CC	GL CT Ref		GL CT Ref CTa
2016	1622	160	(2,415)	CT			CT			CT
2017	1751	160	(2,415)	CT			CT			CTa
2018	1881	160	(2,415)	BLN1			BLN1	BLN1		BLN1
2019	2012	160	(2,415)	CT	BLN1					
2020	2124	160	(2,415)	BLN2			BLN2	BLN2		BLN2
2021	2216	160	(2,415)	CC	BLN2					
2022	2294	160	(2,415)	CT CC				CTa		CC
2023	2362	160	(2,415)	CT				CTa		CT
2024	2429	160	(2,415)	NUC						
2025	2470	160	(2,415)	IGCC	NUC			CC		CT
2026	2495	160	(2,415)	NUC						
2027	2509	160	(2,415)	CT	NUC			CT		CT
2028	2516	160	(2,415)	CC						
2029	2520	160	(2,415)	IGCC, Cta	Cta	Cta		CT		CC

Figure C-3 – Planning Strategy C – Diversity Focused Resource Portfolio

Year	Defined Model Inputs			Capacity Additions by Scenario						
	EEDR	Renewables	Fossil Layups	SC1	SC2	SC3	SC4	SC5	SC6	SC7
2010	298	35	-	PPA's & Acq						
2011	389	48	(226)							
2012	770	145	(226)	JSF CC	JSF CC	JSF CC	JSF CC	JSF CC	JSF CC	JSF CC
2013	1334	286	(935)	WBN2	WBN2	WBN2	WBN2	WBN2	WBN2	WBN2
2014	1596	44	(935)	CTa			CTa			
2015	2069	515	(3,252)	GL CT Ref CT CC			GL CT Ref CT CC	GL CT Ref		GL CT Ref CTa
2016	2537	528	(3,252)	CT			CT			
2017	2828	715	(3,252)							
2018	3116	768	(3,252)	BLN1			BLN1			BLN1
2019	3395	822	(3,252)							
2020	3627	883	(3,252)	BLN2 PSH	PSH	PSH	BLN2 PSH	PSH	PSH	BLN2 PSH
2021	3817	896	(3,252)	CT						
2022	3985	911	(3,252)	CC	BLN1			BLN1		
2023	4143	922	(3,252)	CC						
2024	4295	935	(3,252)	NUC	BLN2			BLN2		
2025	4412	942	(3,252)	IGCC						CT
2026	4502	947	(3,252)	NUC						
2027	4561	948	(3,252)	CT						CC
2028	4602	953	(3,252)	CT						
2029	4638	954	(3,252)	IGCC, Cta	NUC			CTa		CTa

Key:
PPA's & Acq = purchased power agreements, including potential acquisition of third-party-owned projects (primarily combined cycle technology)
JSF CC = the combined cycle unit to be sited at the John Sevier plant (Board approved project, currently under development)
WBN2 = Watts Bar Unit 2 (Board approved project, currently under development)
GL CT Ref = the proposed refurbishment of the existing Gleason CT units
CC = combined cycle
CT/CTa = combustion turbines
PSH = pumped-storage hydro
BLN1/BLN2 = Bellefonte Units 1 & 2
NUC = nuclear unit
IGCC = integrated gasification combined cycle (coal technology)

Figure C-4 – Planning Strategy D – Nuclear Focused Resource Portfolio

Year	Defined Model Inputs			Capacity Additions by Scenario						
	EEDR	Renewables	Fossil Layups	SC1	SC2	SC3	SC4	SC5	SC6	SC7
2010	1300	35	-	PPA's & Acq						
2011	1126	48	(226)							
2012	1394	145	(226)	JSF CC	JSF CC	JSF CC	JSF CC	JSF CC	JSF CC	JSF CC
2013	1795	286	(935)	WBN2	WBN2	WBN2	WBN2	WBN2	WBN2	WBN2
2014	2228	442	(935)	CTa		GL CT Ref	GL CT Ref CT CTa			
2015	2612	515	(5,718)	GL CT Ref CT(2) CC(2)	GL CT Ref		CT(2) CC(2)	GL CT Ref CC		GL CT Ref CTa(2) CC
2016	2846	528	(5,718)	CT			CC	CC		CC
2017	3104	715	(6,972)	CC	CC		CC			CTa
2018	3389	768	(6,972)	BLN1	BLN1		BLN1	BLN1		BLN1
2019	3704	822	(6,972)							
2020	3993	883	(6,972)	BLN2 PSH	BLN2 PSH	PSH	BLN2 PSH	BLN2 PSH	PSH	BLN2 PSH
2021	4092	896	(6,972)							
2022	4040	911	(6,972)	CC (2)						
2023	4042	922	(6,972)							CTa
2024	4303	935	(6,972)	NUC						
2025	4991	942	(6,972)	IGCC	NUC					
2026	5201	947	(6,972)	NUC						
2027	5711	948	(6,972)		NUC					
2028	6198	953	(6,972)	IGCC						
2029	6316	954	(6,972)	SCPC						

Figure C-5 – Planning Strategy E - EEDR and Renewables Focused Portfolio

Year	Defined Model Inputs			Capacity Additions by Scenario						
	EEDR	Renewables	Fossil Layups	SC1	SC2	SC3	SC4	SC5	SC6	SC7
2010	34	35	-	PPA's & Acq						
2011	181	48	(226)							
2012	1136	178	(226)	JSF CC	JSF CC	JSF CC	JSF CC	JSF CC	JSF CC	JSF CC
2013	1664	314	(935)	WBN2	WBN2	WBN2	WBN2	WBN2	WBN2	WBN2
2014	2431	493	(935)							
2015	3479	580	(4,730)	GL CT Ref CTa CC(2)			GL CT Ref CTa CC(2)	GL CT Ref		GL CT Ref CTa
2016	3843	616	(4,730)	CT			CT			
2017	4183	846	(4,730)							
2018	4504	921	(4,730)	CT			CT			CC
2019	4811	994	(4,730)	CC (2)						
2020	5074	1060	(4,730)	CC (2)			CC			
2021	5353	1074	(4,730)	CTa						
2022	5460	1094	(4,730)	BLN1	BLN1			BLN1		BLN1
2023	5599	1107	(4,730)	CT						
2024	5739	1124	(4,730)	BLN2	BLN2			BLN2		BLN2
2025	5815	1133	(4,730)	CT						
2026	5893	1142	(4,730)	CT						CT
2027	5961	1145	(4,730)	CT						
2028	6009	1154	(4,730)	NUC				CTa		CTa
2029	6043	1157	(4,730)	CT				CTa		CTa

Key:
PPA's & Acq = purchased power agreements, including potential acquisition of third-party-owned projects (primarily combined cycle technology)
JSF CC = the combined cycle unit to be sited at the John Sevier plant (Board approved project, currently under development)
WBN2 = Watts Bar Unit 2 (Board approved project, currently under development)
GL CT Ref = the proposed refurbishment of the existing Gleason CT units
CC = combined cycle
CT/CTa = combustion turbines
PSH = pumped-storage hydro
BLN1/BLN2 = Bellefonte Units 1 & 2
NUC = nuclear unit
IGCC = integrated gasification combined cycle (coal technology)